An Object Oriented Design for COVID-19 Diagnostic Imaging

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Abstract

The outbreak of COVID-19 has created a global health crisis and continues to take a toll on the health and well-being of people across the world. Massive testing is required for quick identification of cases and preventing the further spread of the disease. In this paper, we propose a software architecture for deep learning tools for identification of COVID-19 from chest X-ray images.

1. Introduction

Diagnostic testing plays a crucial role to identify people infected with the novel coronavirus - SARS-CoV-2. Due to lack of skilled laboratories and technicians, most clinical laboratories do not have the capability to perform reverse transcriptase-polymerase chain reaction (RT-PCR) test for detecting the virus. The test is a complex process and requires swab collection sticks, storage solution, RNA extraction kits and PCR kits[12]. Shortage of certain chemicals and supplies adds to the struggle of clinical labs world over[8]. Academic institutions, public and private laboratories and corporates across the world are creating global collaboration unlike any in the history for coronavirus medical research[2]. Point-of-care molecular testing, antigen testing, and serological testing in respiratory samples are currently being studied and tested[1]. The clinical value of these tests is not yet known and will take significant time for reliable, massive deployment. Several other diagnostic techniques have shown wide variation in their sensitivity, despite early promise of good performance[3]. At present, RT-PCR testing is the sole preferred method for the virus detection. Although, chest X-ray based diagnosis is very promising, an estimated two thirds of the global population lack access to radiology diagnostics. In this work, we propose a complete software architecture for the deep learning model for detecting COVID-19 from CXR images.

2. Literature Review

Deep learning has propelled remarkable progress in the areas of computer vision and image processing. The success of deep convolutional neural networks for natural images have given hopes for and research towards revolutionizing the field of computer-aided diagnostics. Stanford's machine learning group developed an algorithm that can detect pneumonia from chest X-rays at a level exceeding practicing radiologist[7]. The 121-layer CNN inputs a CXR and outputs the probability of pneumonia along with the heatmap for localizing the areas of images most indicative of pneumonia.

Most patients who reported with COVID-19 had ground glass opacities, peripheral distribution, fine reticular opacities, and vascular thickening in radiological findings[4]. These findings from radiological images provide a solid promise for using deep learning based techniques for detecting COVID-19

2.1. COVID-19 CXR Dataset Generation

For the development of any prognostic or diagnostic tools, data collection and generation are most crucial step. Our dataset comes from open-access COVID-19 repositories, University of Montreal's COVIDx dataset[9]. In the system described in this paper, we use Chest X-Rays for diagnostic imaging. Currently, all images and data used for training the neural networks are obtained from the following URL: `https://github.com/ieee8023/covid-chestxray-dataset`. This dataset gives us insights into the radiological findings of COVID-19 and shows us how to distinguish it from other types of pneumonia.

2.2. Neural Network Model Architecture

In this study, we adapt the COVID-Net[11] deep neural network architecture for detecting COVID-19 from chest X-ray images. COVID-Net models the COVID-19 detection task as a multi-class classification problem, where the input is a frontal-view chest X-ray image X and the output is a tertiary label y 0, 1, 2 indicating the absence of any infection,

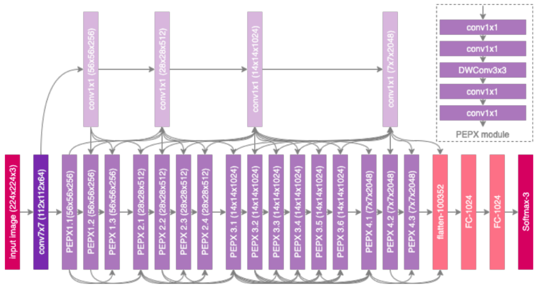

Figure 1. COVID-Net Architecture [10]

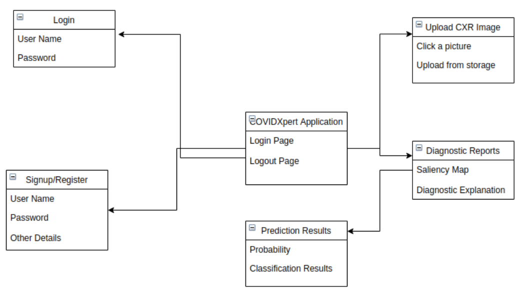

Figure 2. Simplified Class Diagram for COVIDXpert

presence of non-COVID-19 infection or COVID-19 viral infection respectively. This architecture has shown promising results in terms of the accuracy in detecting patients with COVID-19 using chest radiological images. Gradient saliency map may be used to explain why the deep network came up with certain prediction. We compute the pixel-wide impact on a specific output and overall outputs[6].

3. COVIDXpert System Architecture

The content of the software is described and demonstrated by the software architecture. These models help software developers to analyze the software at the early stage of software development. With the help of these design models and documents, clients can look at the structural features of the software. In order to not exceed the current limited real time computing power, the entities used in the architectural models are restricted to a minimum set of necessary features. This object-oriented design is flexible enough to include more details in future.

3.1. Requirements

In order to enable computer-aided-diagnosis of COVID-19 from a mobile application, we require either a digital CXR image or the CXR image captured by smartphone camera to be uploaded to the application by the user. The user may also update his user profile, medical history and

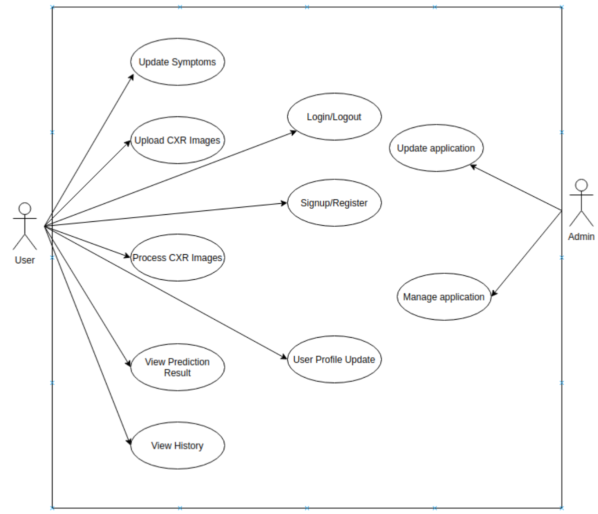

Figure 3. Use Case Diagram for COVIDXpert

other symptoms if any. Also, it is assumed that the input information coming from the user is correct.

1. Functional Requirements: The users should be able to enter their personal details and upload a picture of the CXR image from their mobile or web application. The signup and login pages should be able to accept text information from the users. The application should be able to store and retrieve images from the local image storage database.

2. Non-Functional Requirements: Reliability and robustness of the application is relevant for the entire software system. Real-time computing capability, interoperability with various types of computer or smartphone architectures, modular design, and a flexible interface for ease of integration are some other key requirements.

3.2. Application Design

A primary function of this software is to serve as an Application Programming Interface that enables any user to upload a chest X-ray to the trained model for detecting the presence of COVID-19 infection.

The application has a start page and thereafter, the user should be able to sign-up or login into his/her account. Then the next page should allow the user to upload an image or click a picture from their application to be able to send an image to the trained model for prediction. After the trained model is reconstructed on the browser itself, the model can now predict the probability of the presence of COVID-19 from CXR images. The results are then displayed on the

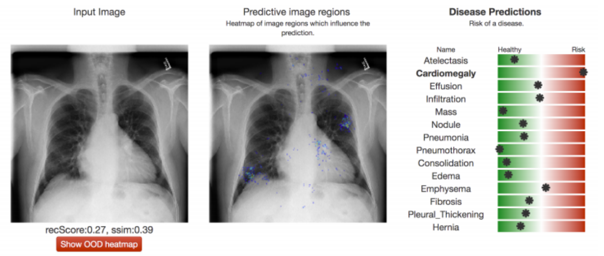

Figure 4. An example of deep-learning prediction on X-ray images [6]

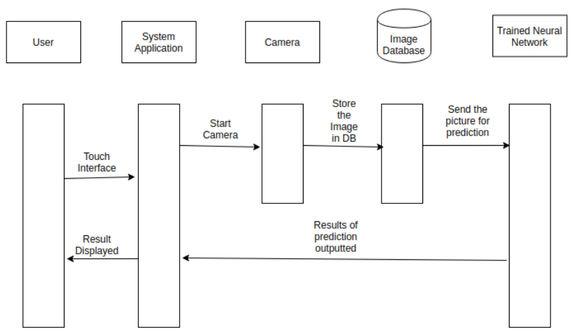

Figure 5. Sequence Diagram for COVIDXpert

application interface. This modular design of the application follows the software architecture principles.

3.3. Web Computation

TensorFlow.js is compatible across browsers and is used in this project for prediction on the browsers. Models trained in any framework can be transformed into the TensorFlow framework using the ONNX pipeline[10]. The model's graph and weights are packaged into files and loaded using a script running on the browser. The model's graph is then reconstructed. After the weights are loaded, the script can process images and execute the computation graph. The prediction results are then displayed on the browser.

4. Conclusion and Future Work

In this work, we demonstrate the software architecture of a tool to aid in diagnosing chest X-rays. This may be beneficial for developers to work on creating new practical deep learning applications for aiding in computer-aided radiological diagnosis. We believe that such solutions tend to bridge the gap between computer scientists and the medical community.

Other possible avenues are proof-of-concept on COVID-19 diagnosis from cough audio clips[5]. The application, if enabled with real-time location monitoring capability, may be used for contact tracing as well. Though these systems are not designed to compete with molecular testing methods, these tools offer a complementing tele-testing tools which may be deployed anywhere and anytime. This allows channeling the clinical testing and treatment to those who need it the most.

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